DTU Library

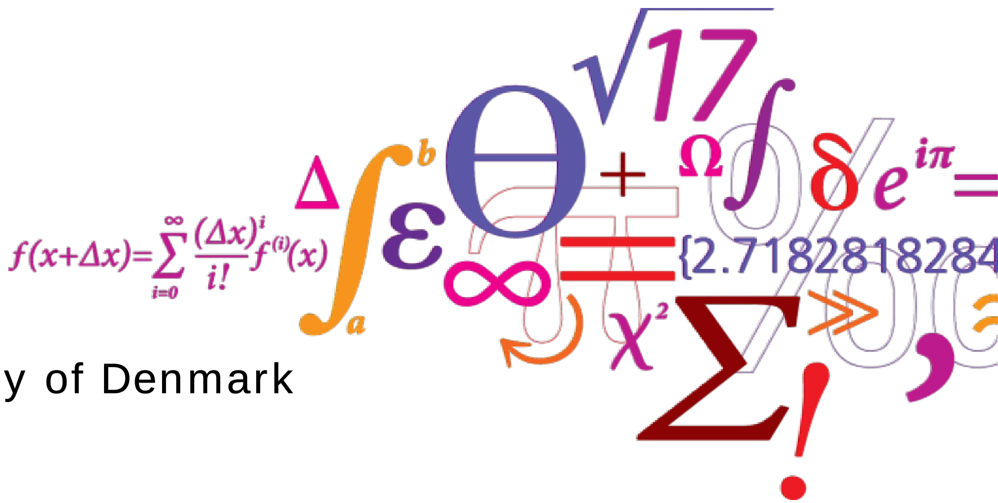
Research and Innovation at DTU Wind Energy

Madsen, Peter Hauge

Publication date:
2012

Research and Innovation at DTU Wind Energy

Presentation at the Japanese-Danish Joint Workshop
Future Green technology
10-12 December 2012, Hakata Japan



Peter Hauge Madsen
Head of Department,
DTU Wind Energy, Technical University of Denmark

Outline

- DTU Wind Energy
- Context
- Research & research infrastructure
- Innovation and industry cooperation
- International cooperation

Poul la Cour at Askov 1891-1903

The new 6 MW offshore wind turbine by Siemens, from http://www.siemens.com/press/en/presspicture

Wind technology expertise

Risø DTU
National Laboratory for Sustainable Energy

Wind Energy Division

Risø DTU
National Laboratory for Sustainable Energy

Materials Research Division

Fluid Dynamics

Composite Mechanics

DTU Wind Energy
Department of Wind Energy

> 240 staff members
Including 150 academic staff members and 50 PhD students

- Composites and Materials Mechanics
- Materials Science and Characterisation
- Fluid Mechanics
- Test and Measurements
- Wind Turbines Structures
- Aeroelastic Design
- Meteorology
- Wind Energy Systems

DTU Wind Energy - 2012

Quality
Scientific excellence

Relevance
Strategic research programmes

Impact
On society

Wind Energy Systems
- Wind resources and siting
- Wind power integration and control
- Offshore wind energy

Wind Turbine Technology
- Aero-elastic design
- Structural design and reliability
- Remote sensing and measurement tech.

Wind Energy Basics
- Aero and hydro dynamics
- Boundary layer meteorology and turbulence
- Light, strong materials

Research

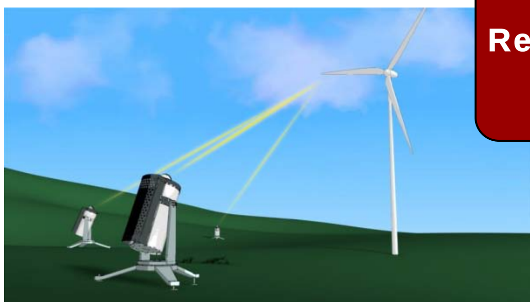
Innovation

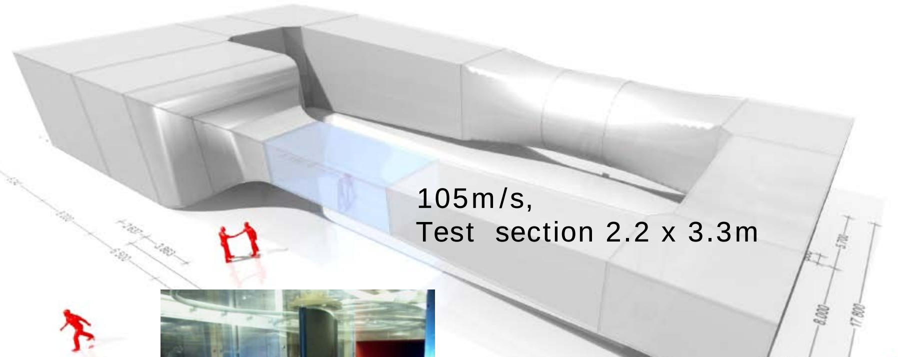
Public sector support

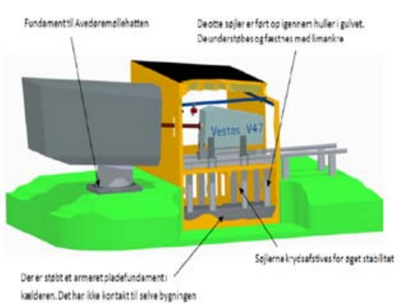
Education

Experiments, Validation and Test

Research and test facilities



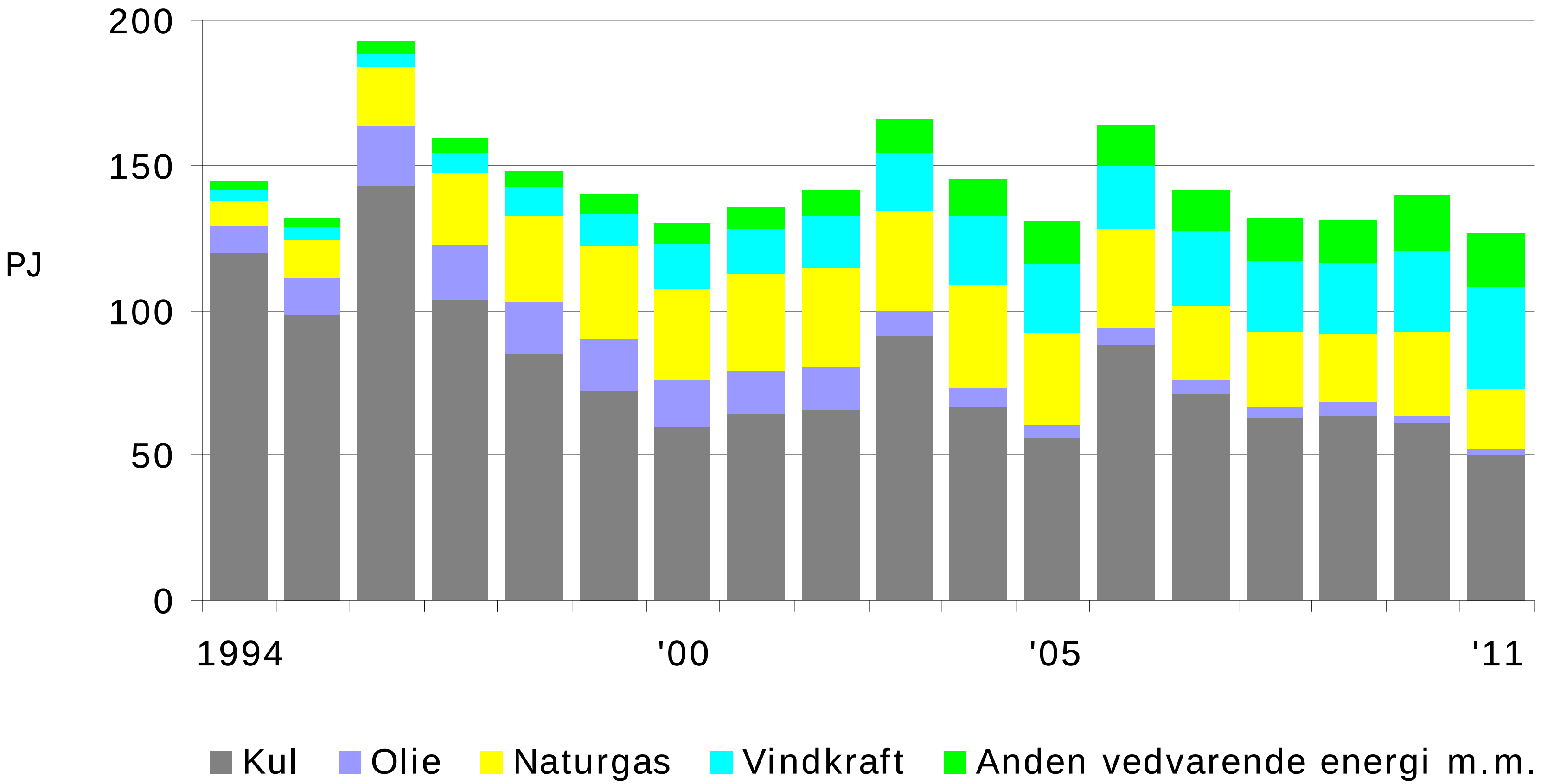




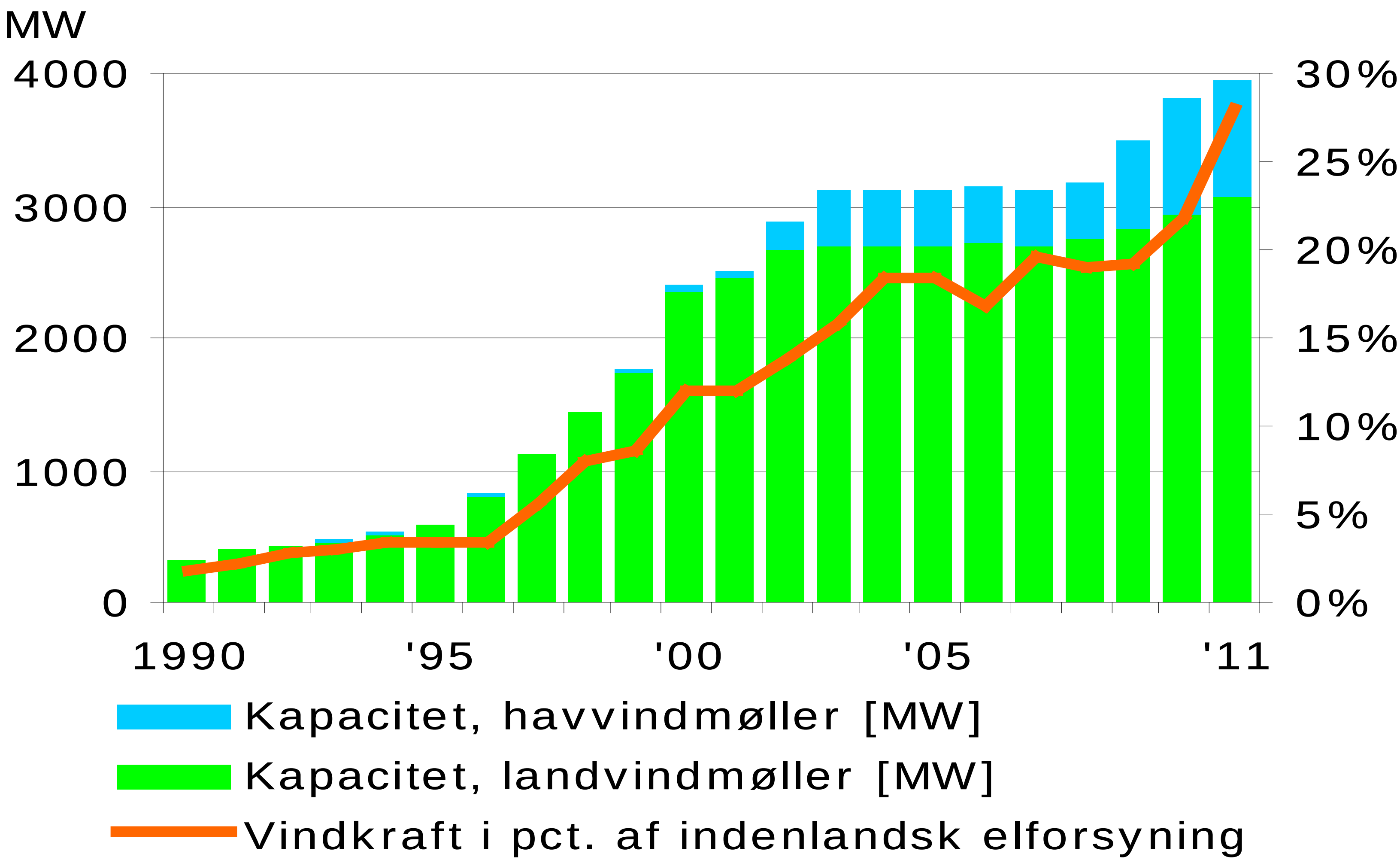
Wind Energy Education Programmes

- Int. M.Sc in Wind Energy:
  - Mechanics: 30 students per year
  - Electronics: 10 students per year
  - About 50 thesis work per year
- Nordic Master's programme in Sustainable Energy
- European Eramus Mundus Wind Master
- PhD research school (DAWE):
  - about 50 PhD students at DTU
- European Academy of Wind Energy

Electricity production and used fuel



Wind Power in Denmark



Danish Energy Policy Goals & Industry

- 100 pct. renewable energy in 2050
- 100 pct. renewable energy in to electricity and heat supply in 2035
- No coal and oil from 2030

- Wind power covers 9 pct. of gross energy consumption in 2020.
- Wind Power covers 49,5 pct. of electricity consumption in 2020.

- EU target for DK:
- Renewable energy covers 30% in 2020, with 10 % i transport (DK expects 35% in 2020)

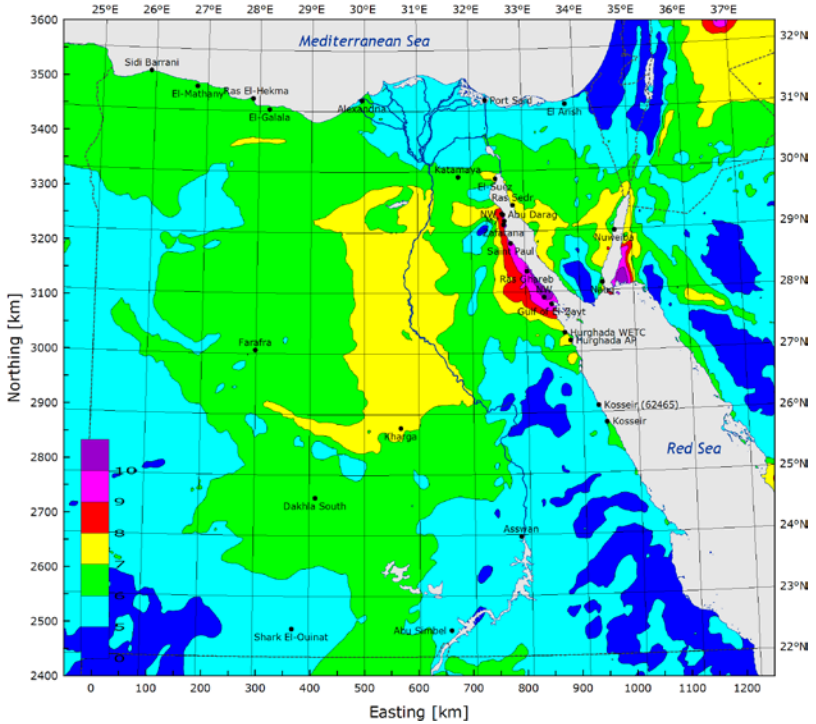
2011 Industry statistics

- Employment 25.550
  - 45 % manufacturing
  - 13 % test and product development

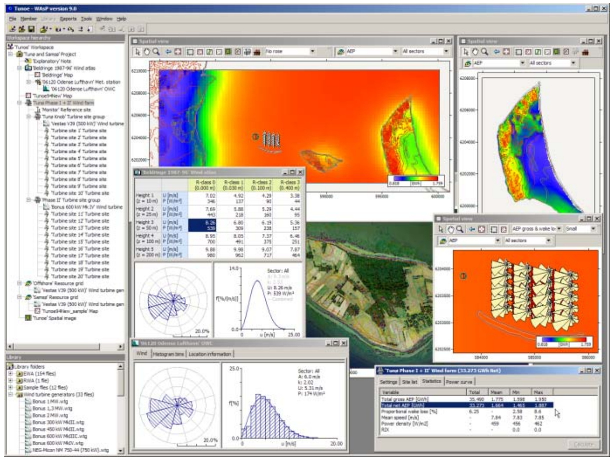
- Turnover in Denmark 51.8 billion DKK
- Export 38.8 billion DKK
- Global turnover 102.8 mia DKK

Wind Power Meteorology
tools and maps

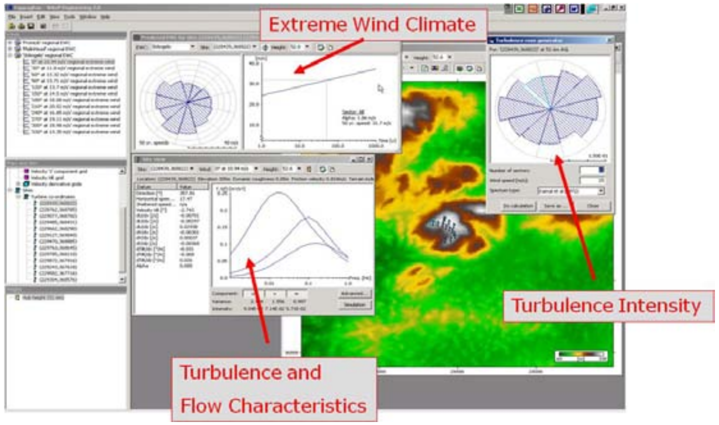
Wind Atlas for Egypt (2006)



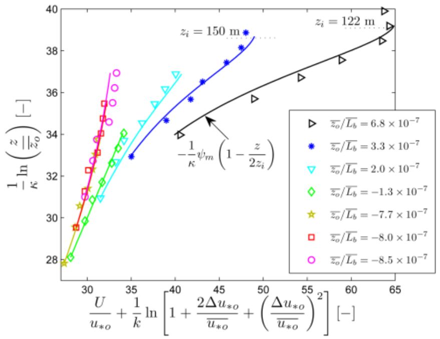
WAsP – the Wind Atlas Analysis and Application Program



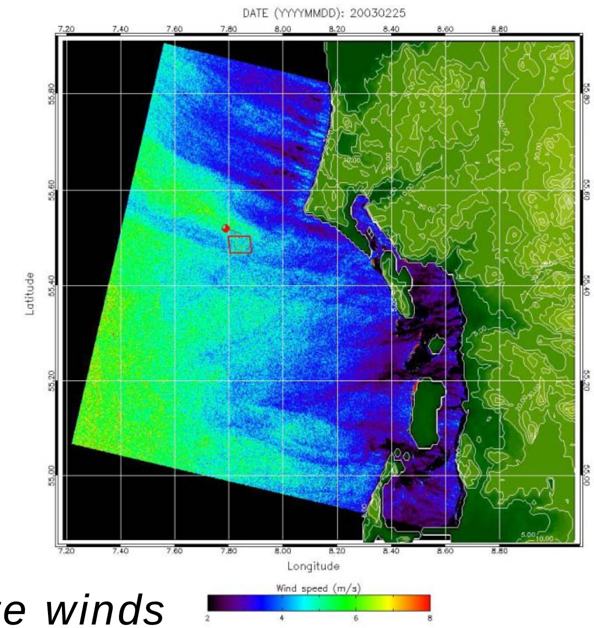
WAsP Engineering



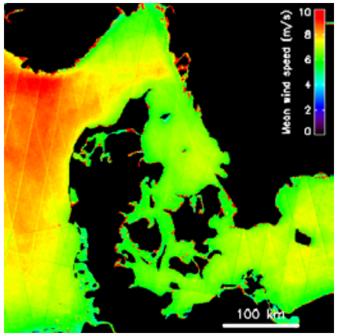
Offshore Wind Conditions



Lidar wind data and model from Horn's Reef offshore

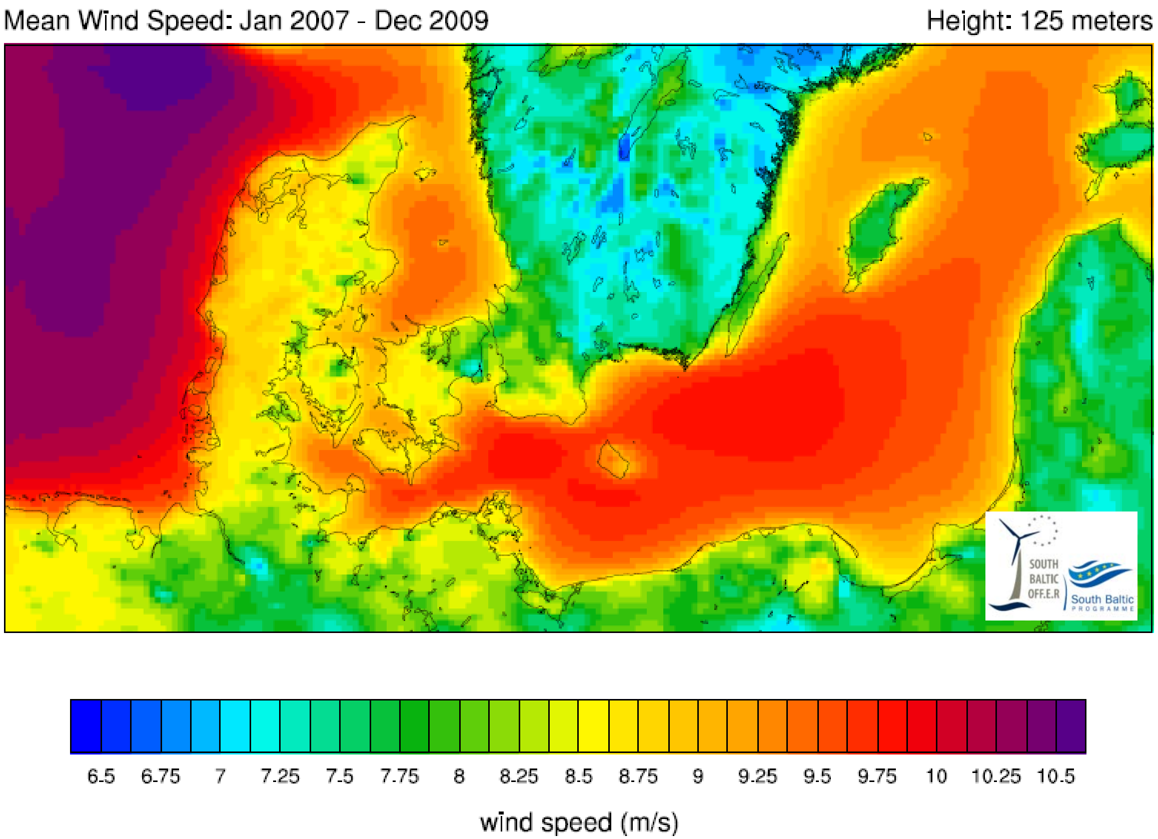


Satellite winds showing the wake at Horn Reef wind farm. Mean wind speed map using satellite Envisat ASAR.



- Ocean winds
- Lidar observations and modelling
- Wind resource mapping using satellite data
- Mesoscale modelling
- Meteorological mast observations
- Wind farms shadow effect
- Satellite observations

Wind Atlas update



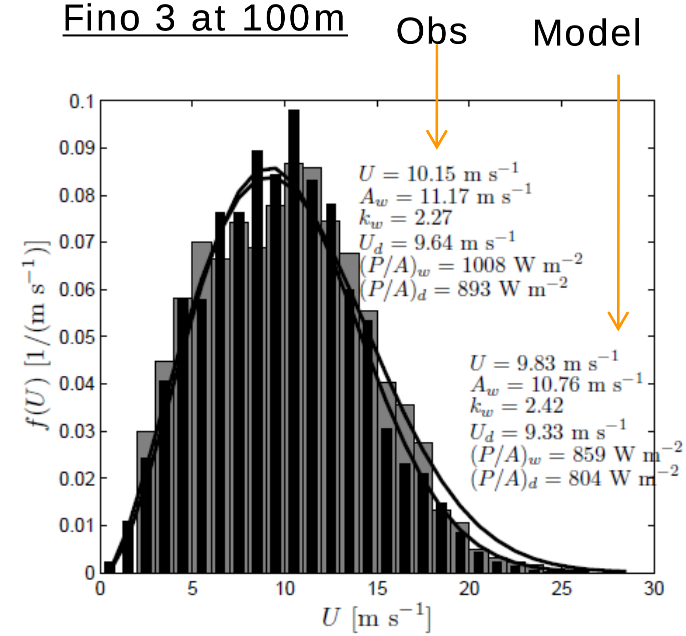
Wind atlas for South Baltic 5 km WRF simulations

Novel features:

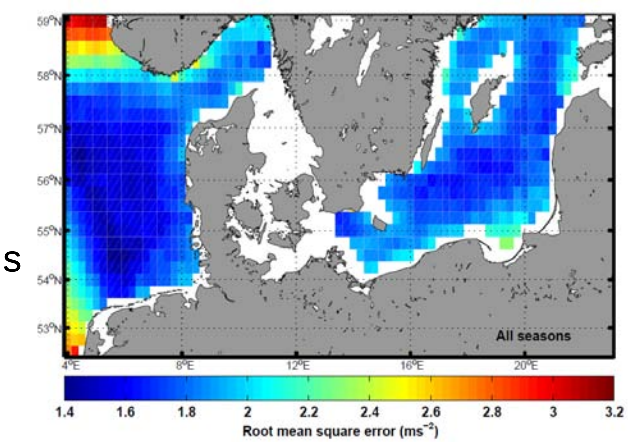
- Verification against high (100 m) offshore measurements
- Comparison over large spatial extent against QuikScat winds
- Climatologies can be calculated for arbitrary periods by applying a wind classification weighting system

DTU Wind Energy, Technical University of Denmark

Fino 3 at 100m



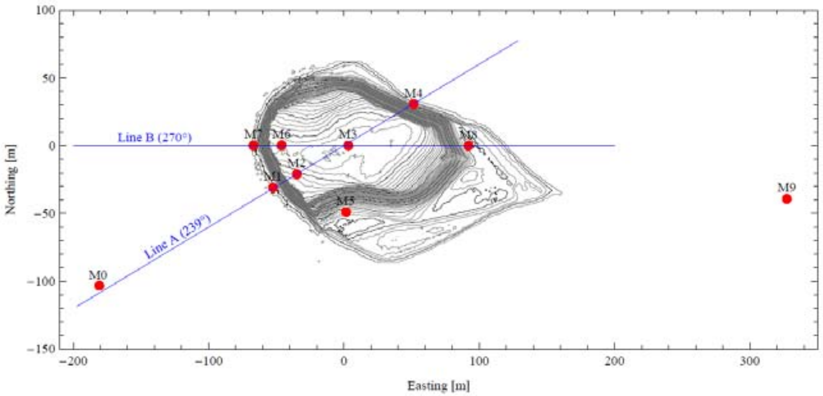
10 m QuikSCAT comparsion



Wind conditions in complex terrain

Bolund experiment

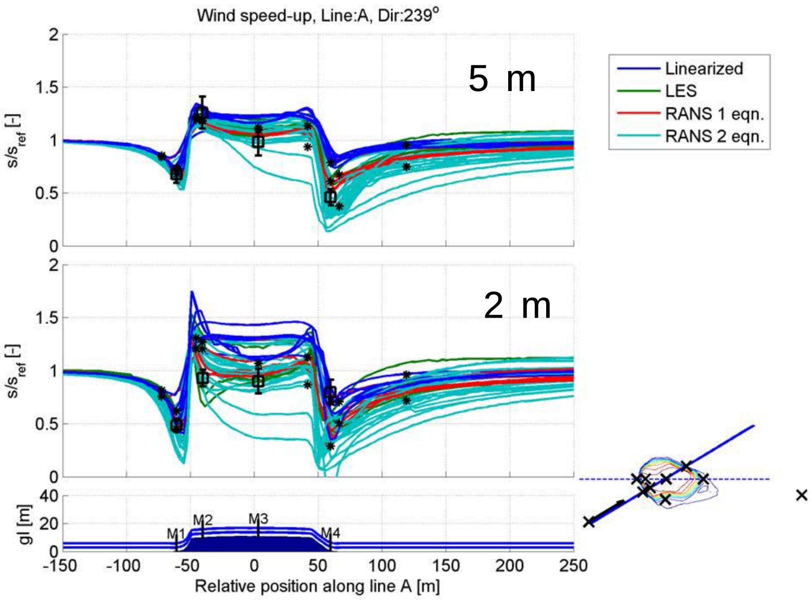
- Well-defined inflow conditions
- Roughness change
- Steep escarpment / “complex”
- Intercomparison study of numerical micro scale flow models



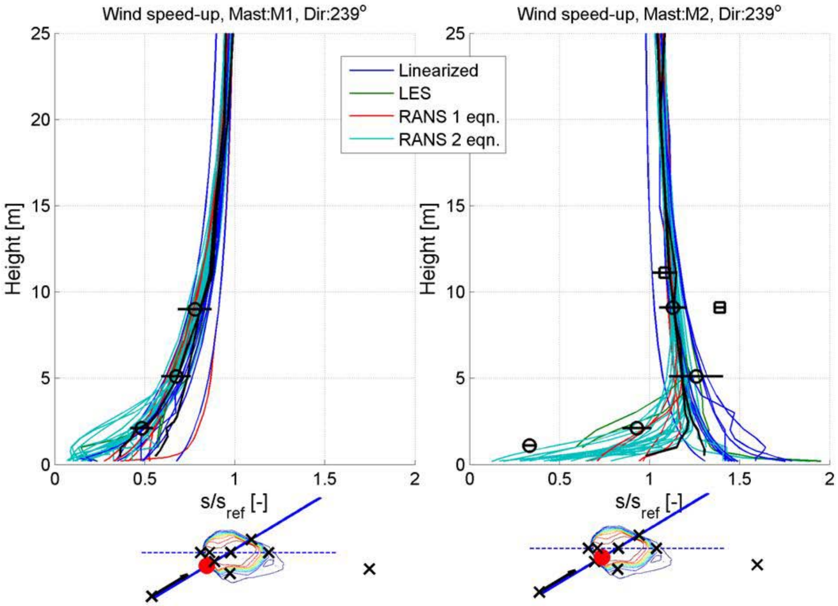
Mast Positions
CFD were used to find the 10 positions

Numerical results

Speed-up along line A

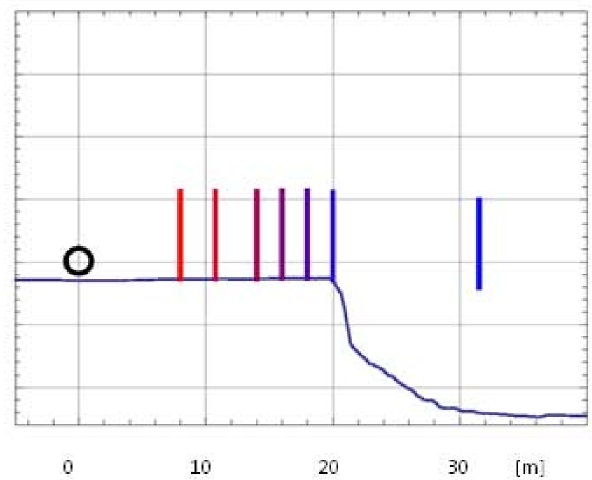


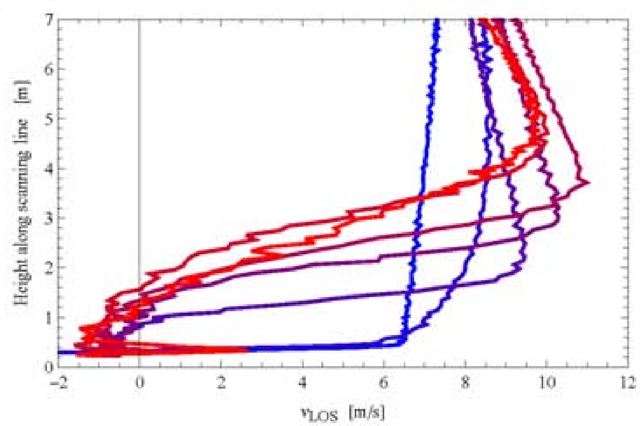
Speed-up at M1 & M2

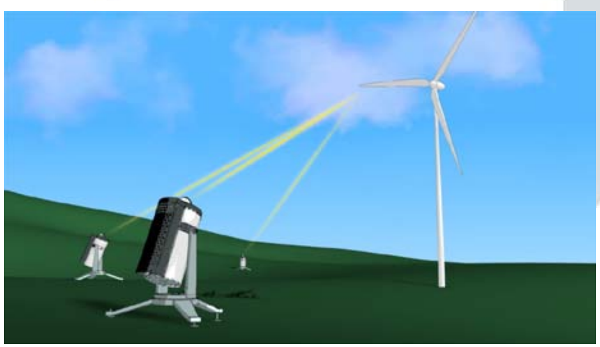


Mean Error:	**26%**
Linearized:	**35%**
LES:	**26%**
RANS 1 eqn.:	**25%**
RANS 2 eqn.:	**20%**

WindScanner.dk - Bolund Hill Experiment - October 2011:

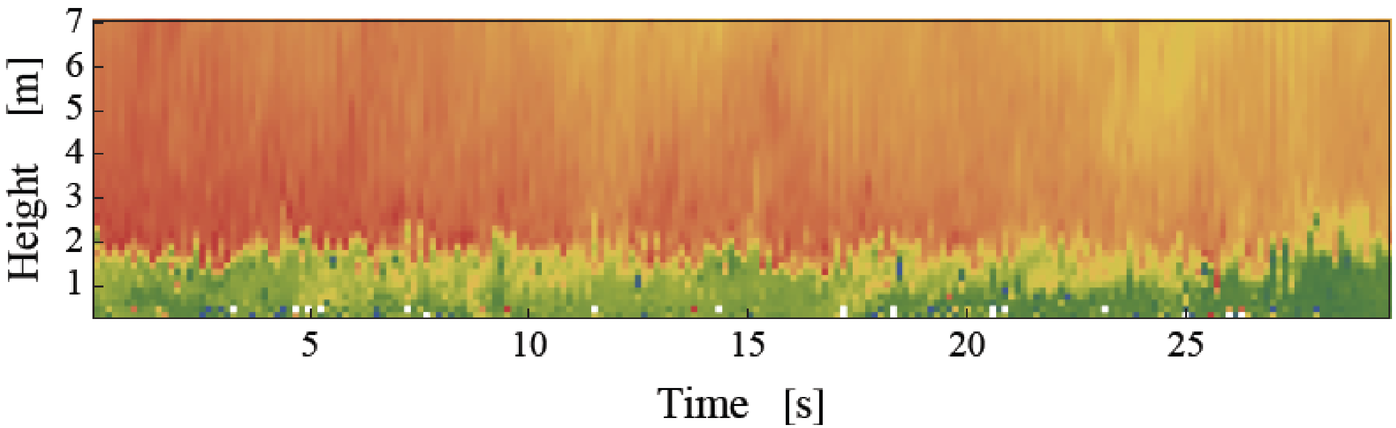


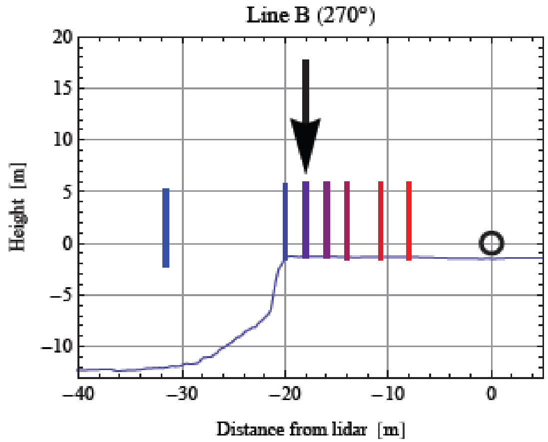


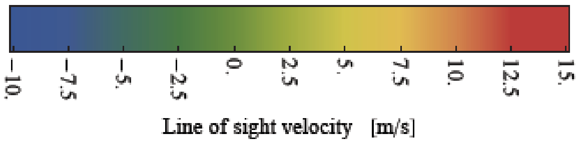


Half a minute of scanning data

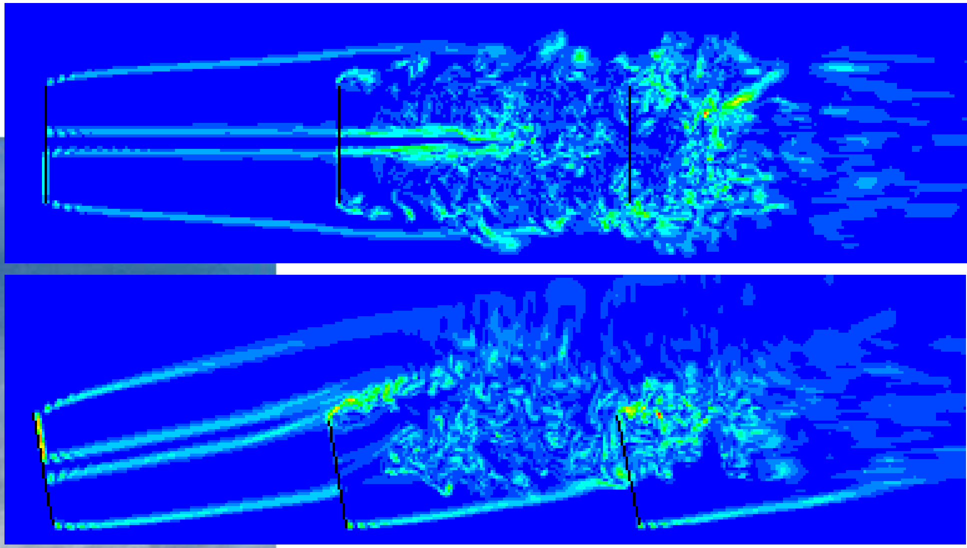
390 line-of-sight velocities per second







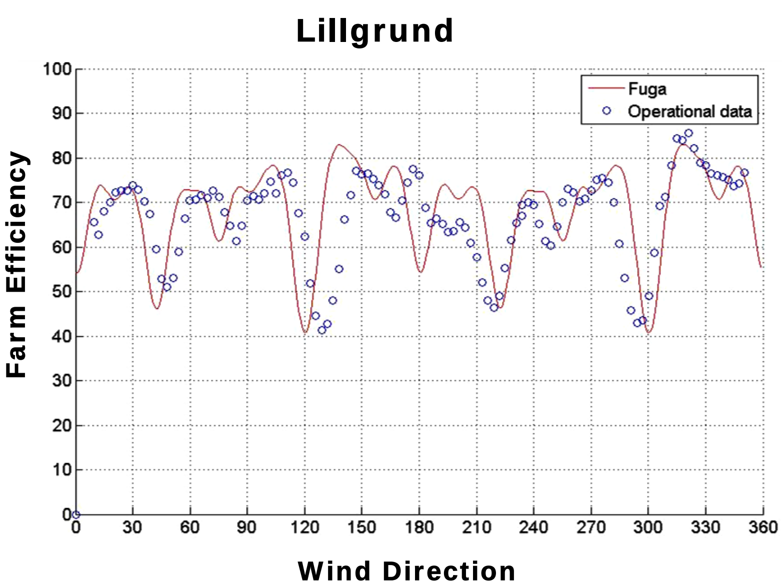
Wake effects – a complex flow essential for performance and loads

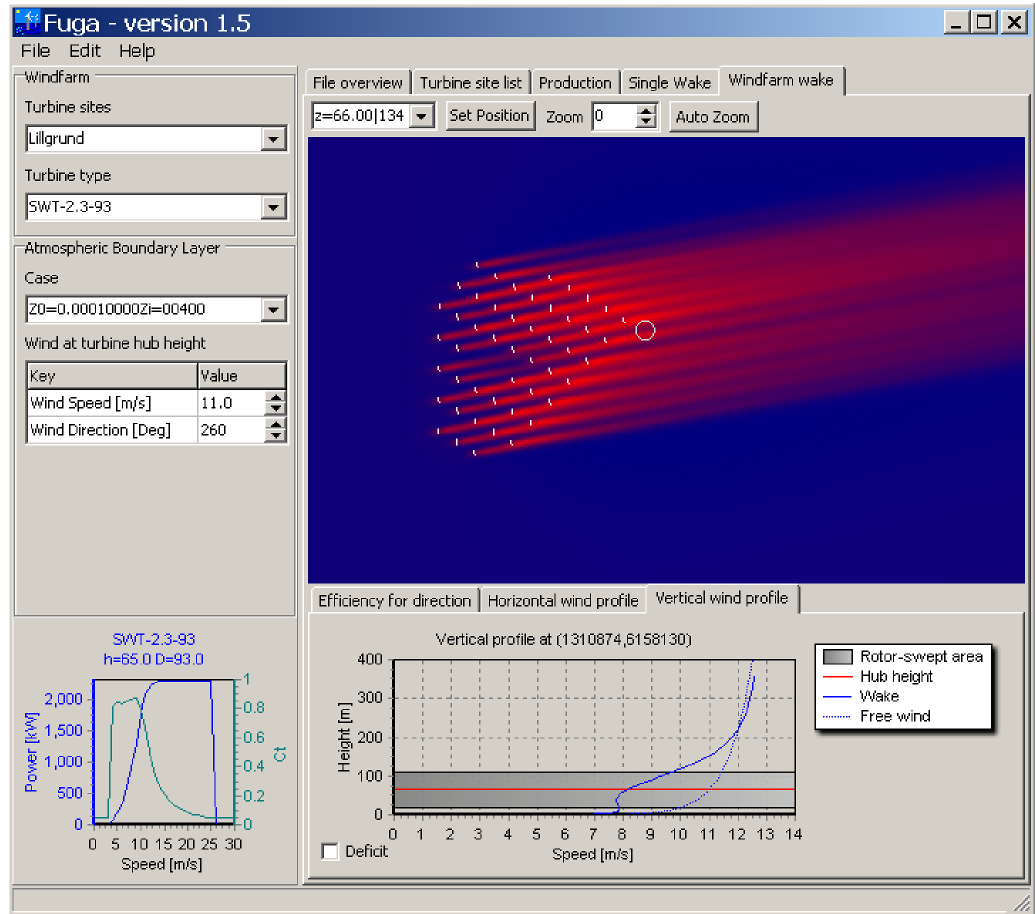


CFD – Large eddy simulation

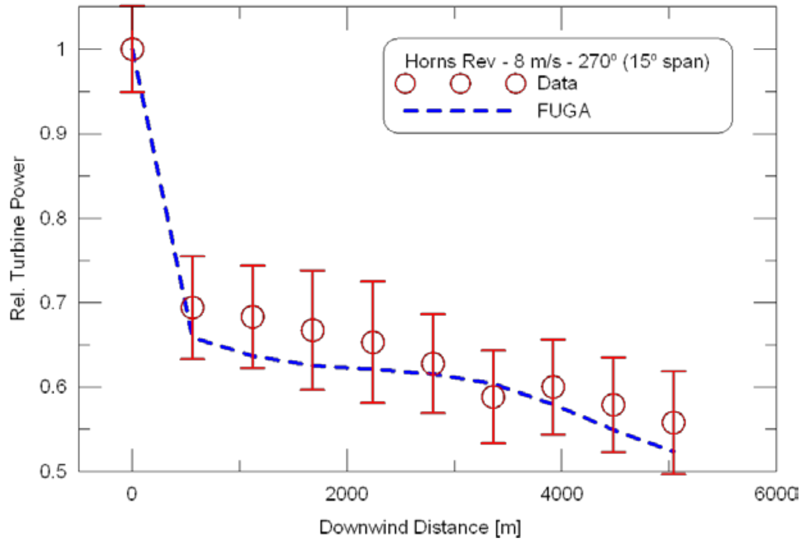
Fuga – a new wake model

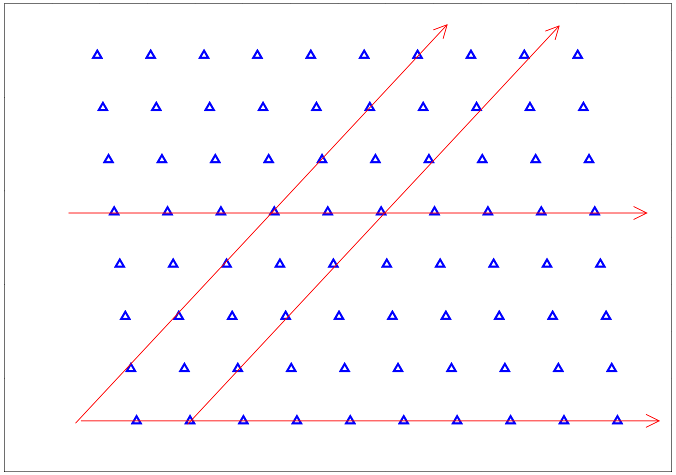
- Linearised CFD
- 10^6 times faster than conventional CFD
- Supported by Carbon Trust
- It Works!

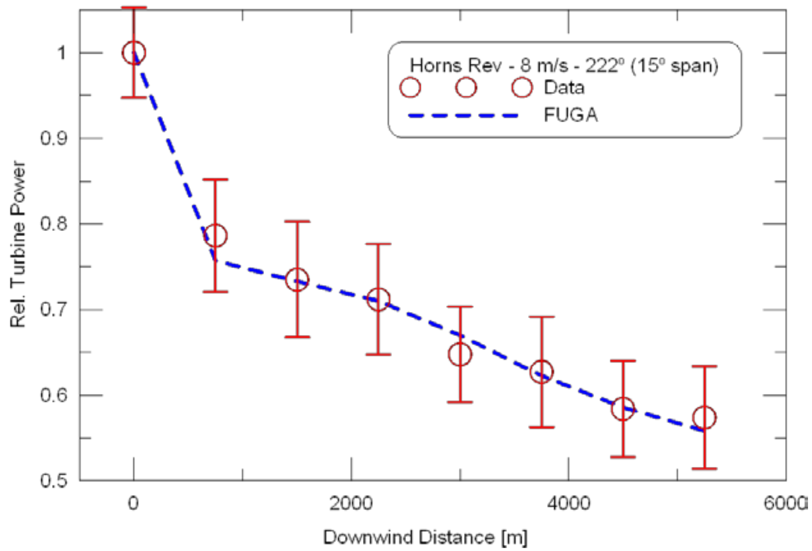




Validation: Horns Rev data. 8 m/s



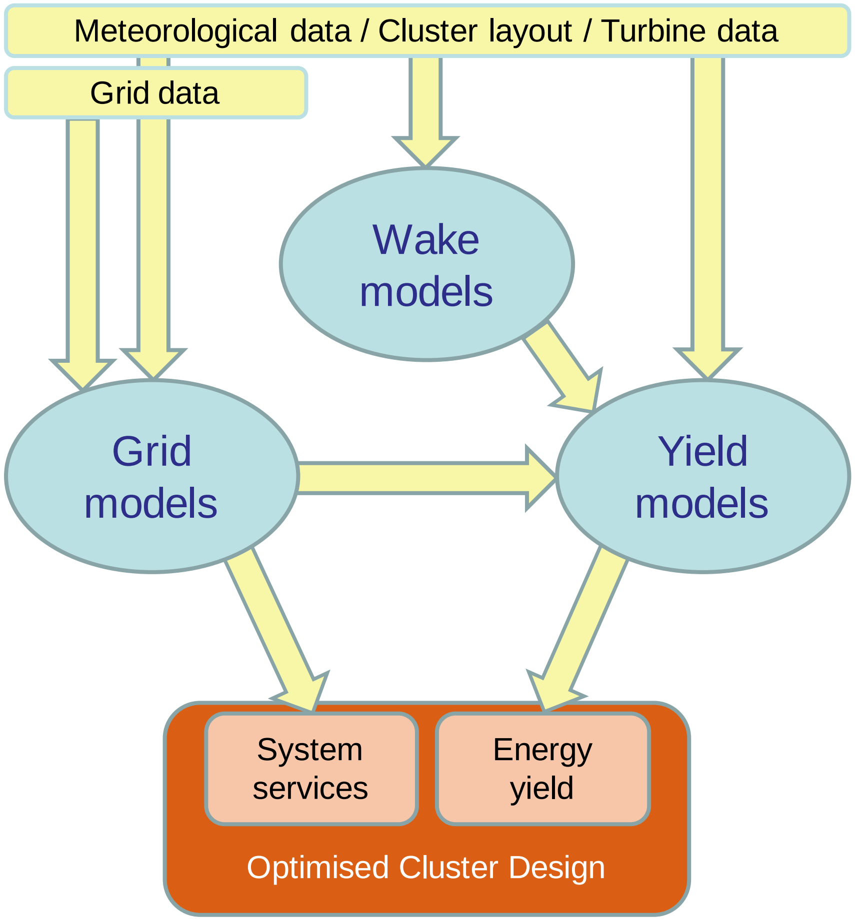




Simple closure: $\nu_t = \kappa u_* z$
No adjustable parameters!

EERA-DTOC Integrated design tool

- Integrate existing atmospheric and wake models from single wind farm to cluster scale.
- Predict energy yield precisely through simulation.
- Interconnection optimization for grid and offshore wind power plant system service.
- Validation of the newly integrated existing models based on wind farm observations.

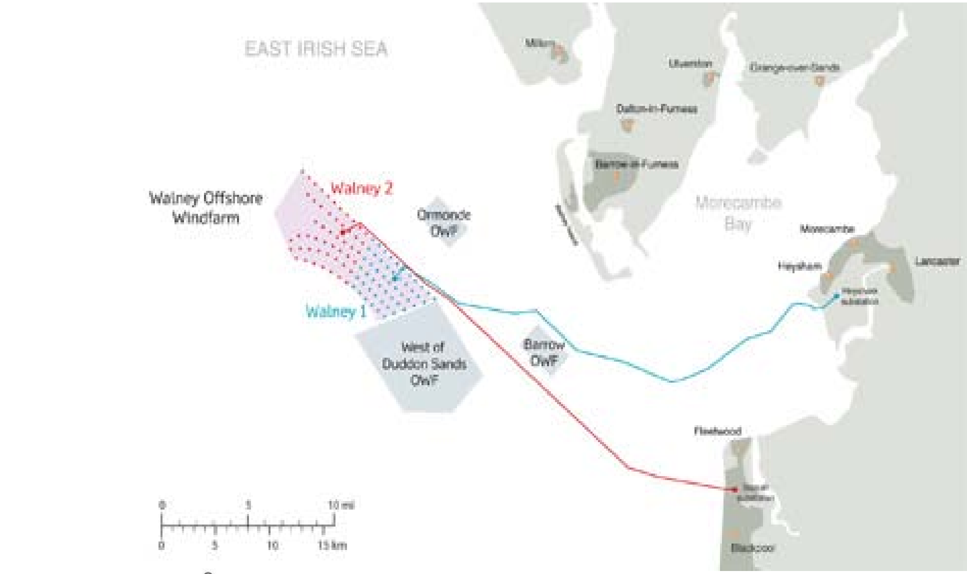


The Walney Offshore Wind (WOW) Project

•Comprehensive loads validation on a state of the art 3.6MW wind turbine
•Collaboration with Siemens Wind Energy and DONG energy

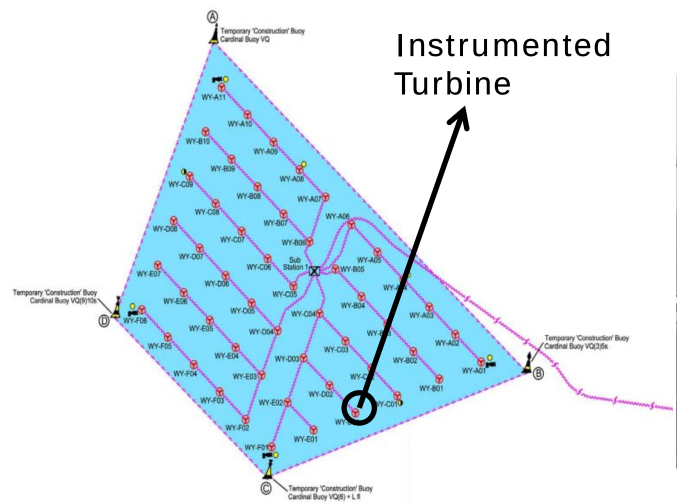
Key Measurements

- Nacelle mounted LIDAR for wind measurements
- Wave sonar and Buoy at turbine
- Accelerometers, strain gauges on
- Blade root, drive train, tower and foundation



•Scientific Objectives

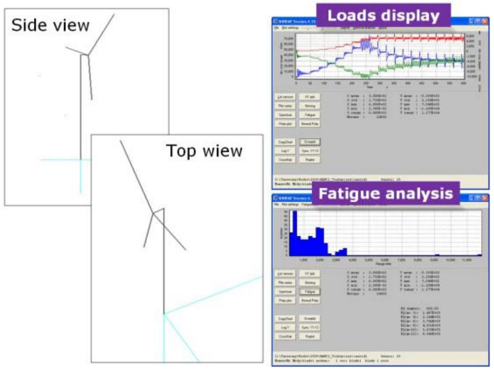
- Validation of the dependencies of design loads
- Prediction of turbine net damping
- Advanced wind/wave correlation studies
- Wake effects on loads



HAWC2 – Risø DTU's code for wind turbine load and response

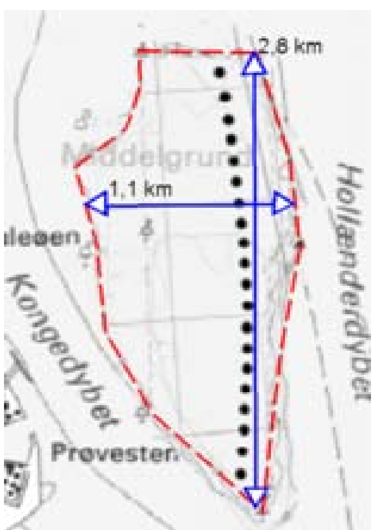
- **A tool for simulation of wind turbine load & response in time domain.**
  - Normal onshore turbines; 3B, 2B, pitch control, (active) stall
  - Offshore turbines (monopiles, tripods, jackets)
  - Floating turbines (HYWIND, Sway, Poseidon).
  - Based on a multibody formulation, which gives great flexibility

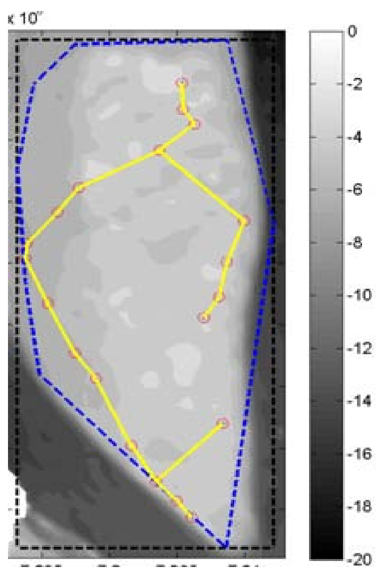
- **It is a knowledge platform!**
  - New research/models are continuously implemented and updated.
  - Core is closed source. E.g. Structure, aerodynamics, hydrodynamics, solver…
  - Submodels are open-source. E.g. water kinematics, standard controllers, generator models.



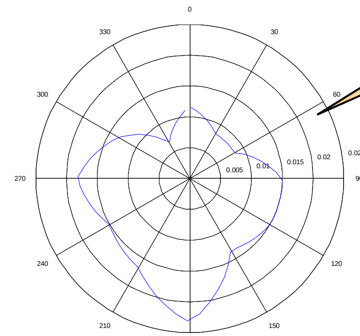
Topfarm wind farm optimization approach - loads and power

- Optimum wind turbines position for the lowest cost of energy
- Wake modeling using DWM (Dynamic Wake Meandering)
- Quick lookup for power and fatigue loads in a database based on HAWC2 aeroelastic simulations
- Cost function including: Annual energy production and costs of: Turbines, Grid, Foundation and O&M



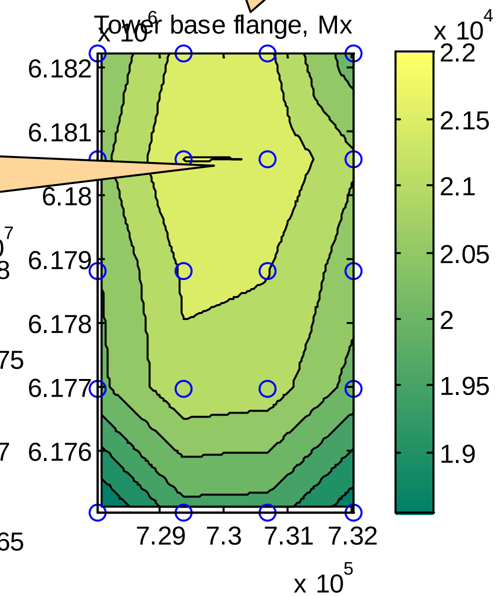


Example: A 20 WT wind farm

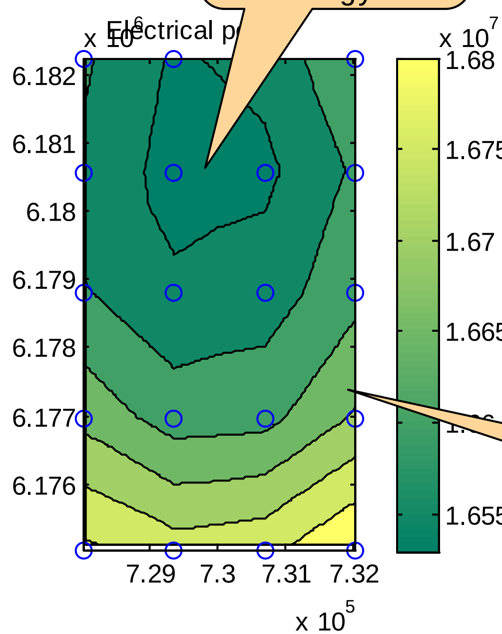


Wind rose

Tower base lifetime fatigue loads in wind farm

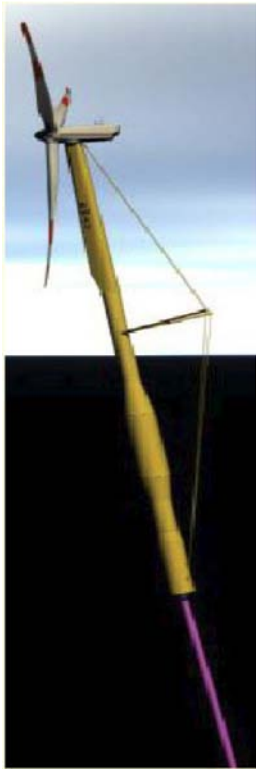


Turbines in wake have higher loads produce less energy!!

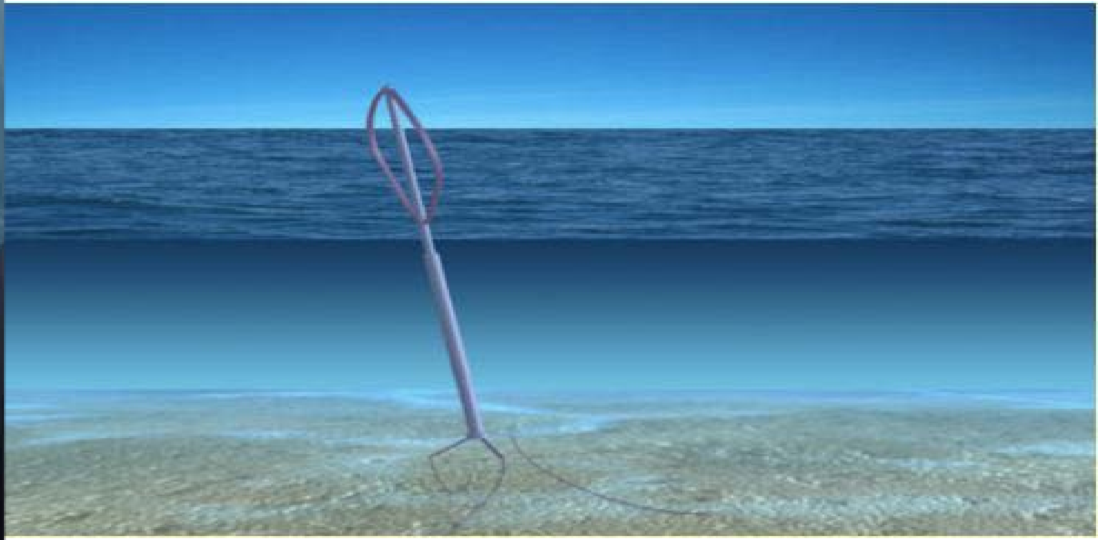


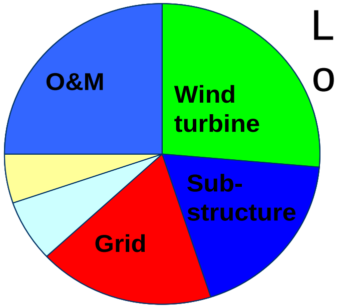
Annual energy yield for each turbine

New concepts offshore



Floating turbines





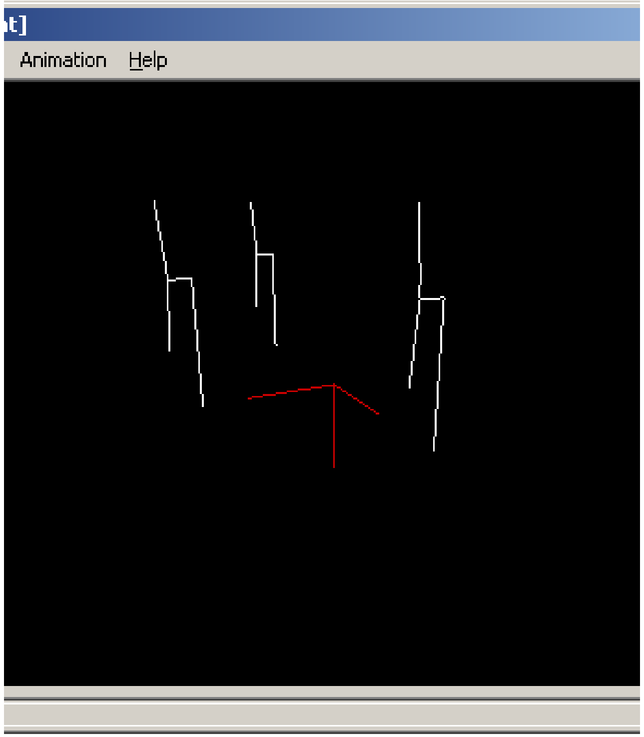
Life cycle costs offshore

Combined wind and wave energy converters

Poseidon: Modeling Challenges

- Three rotors in one simulation
  – Structural modeling already possible in the multi-body formulation
  – Aerodynamic model updated to handle this
- Wake from upwind rotors
  – Already possible with the dynamic wake meandering model in HAWC2

- Large water surface area
  - Full coupled HAWC2-WAMSIM simulations
    - HAWC2 validated aeroelastic code
    - WAMSIM validated radiation/diffraction code for dynamic of floating structures from DHI
    - WAMSIM recode to HAWC2 dll-interface format
    - Ordinary HAWC2 turbine model
    - Ordinary WAMSIM model
    - Full system solved by HAWC2



Risø Hawc2 Overview

Collaboration with industry

DTU offers

- Research cooperation
- Software with training
- Standardization
- Licenses / patents
- Technology development services
  - Applied R&D
  - Consulting: Analysis and studies
  - Testing & measurements
- Education and training
  - PhD programmes
  - Training courses
- Dialogue & access to Danish wind cluster and international network

Industry partners

- Wind Turbine manufacturers
  - Vestas
  - Siemens
  - Gamesa
  - Repower
  - GE
  - Envision
  - ...
- Energy companies
  - Dong Energy
  - Vattenfall
  - EON
  - ...
- Component suppliers
  - LM
  - ...

Risø Test Stations – Prototype Testing

5 test beds

< 165 m

< 8 MW

Spacing 300 m

7 test beds

< 250 m

< 16 MW

Spacing 600 m

Østerild Test Center

Siemens 6 MW – 154 m

Inaugurated 6 Oct 2012

www.windturbinetest.dk

Test bed 1.	
Total height	210 meter
Nominal max power	16 MW
Diameter less than	180 meter
Test bed 4	
Total height	250 meter
Nominal max power	16 MW
Diameter less than	230 meter
Specifications for both test sites:	
Meteorology mast up to	250 meter
Distance WT to met mast	500 meter
Distance between WT’s	600 meter
Average wind speed >	8 m/s

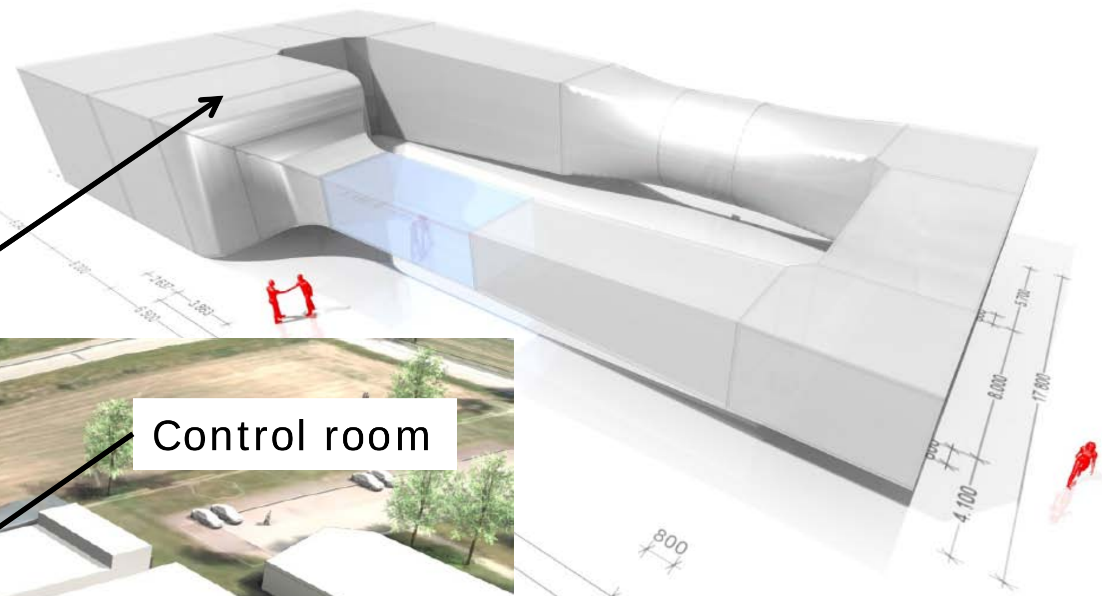
Wind turbine blade testing

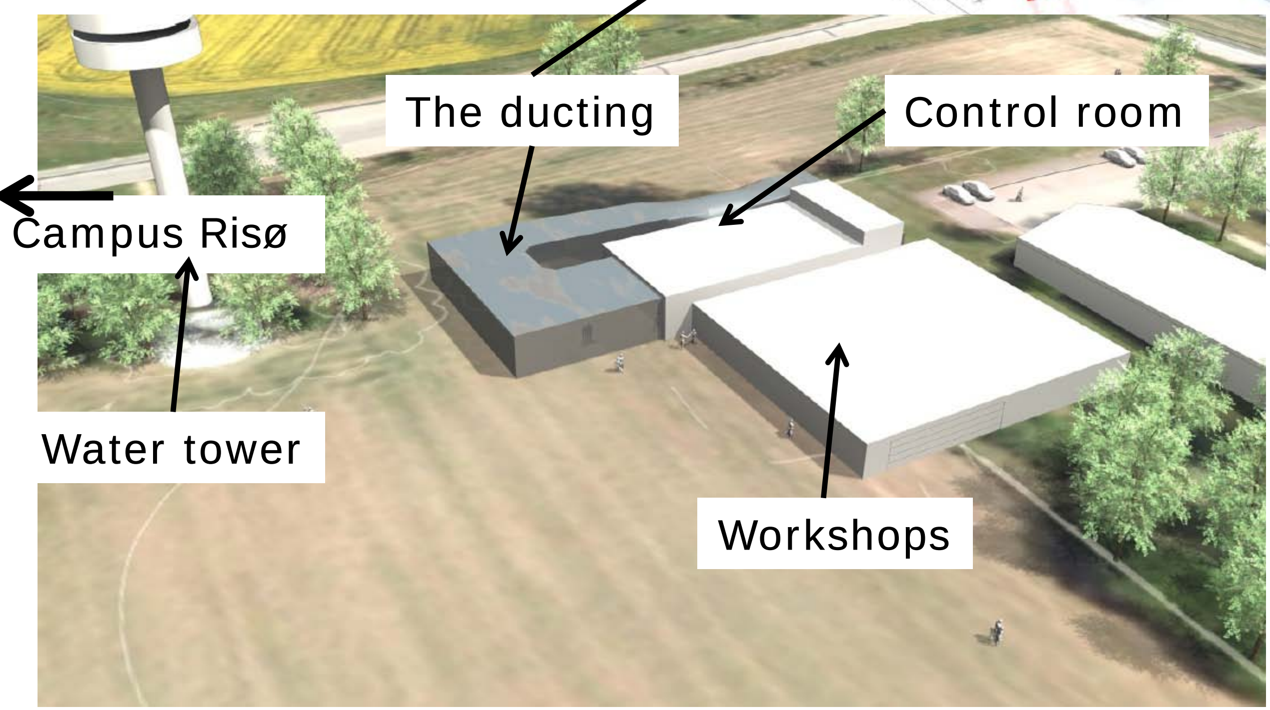
F

Commercial testing at Blade Test centre A/S, a private limited company with the following shareholders:

Det Norske Veritas AS
Technical University of Denmark
FORCE Technology

A large national wind tunnel at Risø Park



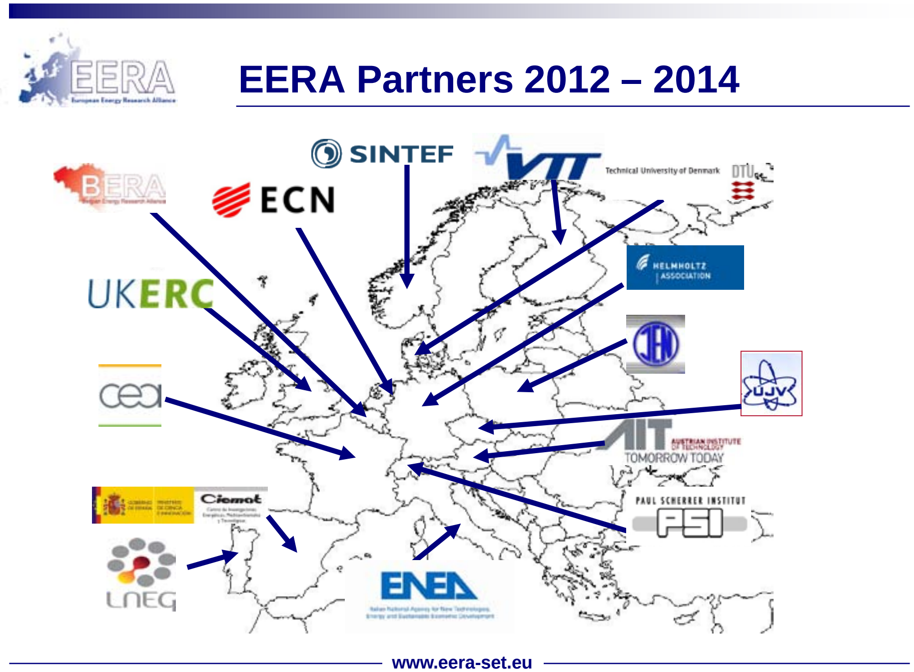


105m/s,
Test section 2.2 x 3.3m

International collaboration

International:

- IEA Wind R&D
- EAWE – European Academy for Wind Energy
- EWEA
- European Wind Energy Technology Platform (EWI)
- EERA – Joint programme on wind energy
- Clean Energy Ministry Initiative (Global wind- and solar atlas)
- Bilateral cooperation



Ambition

The EERA Joint Programme on Wind Energy aims at accelerating the realization of the SET-plan goals and to provide added value through:

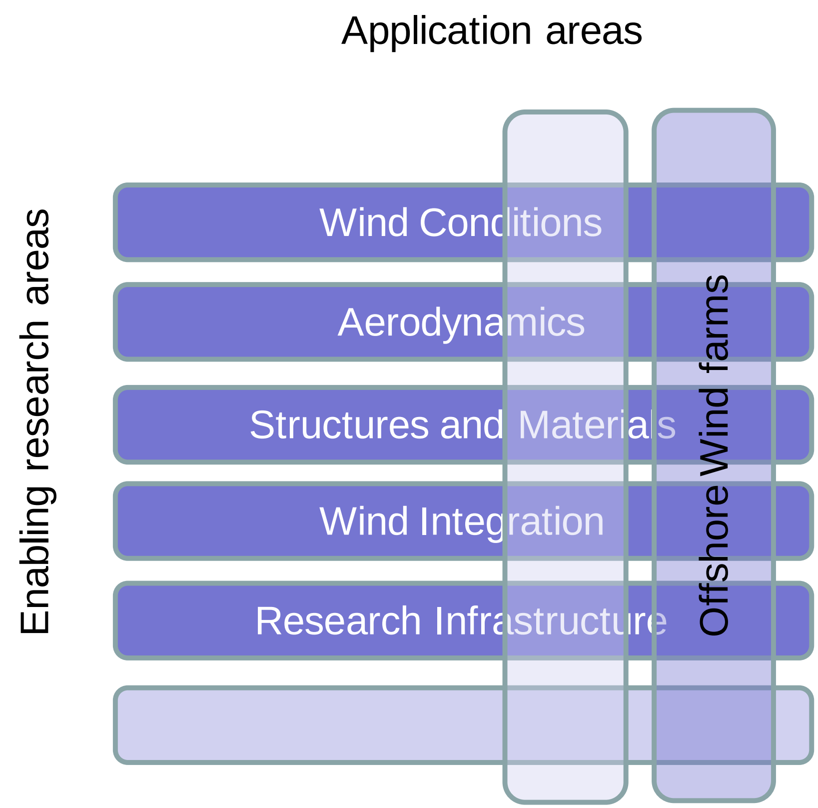
- Strategic leadership of the underpinning research
- Joint prioritisation of research tasks and infrastructure
- Alignment of European and national research efforts
- Coordination with industry, and
- Sharing of knowledge and research infrastructure.

.

Structure of the Joint Programme

The joint programme comprises the following 5 sub-programmes:

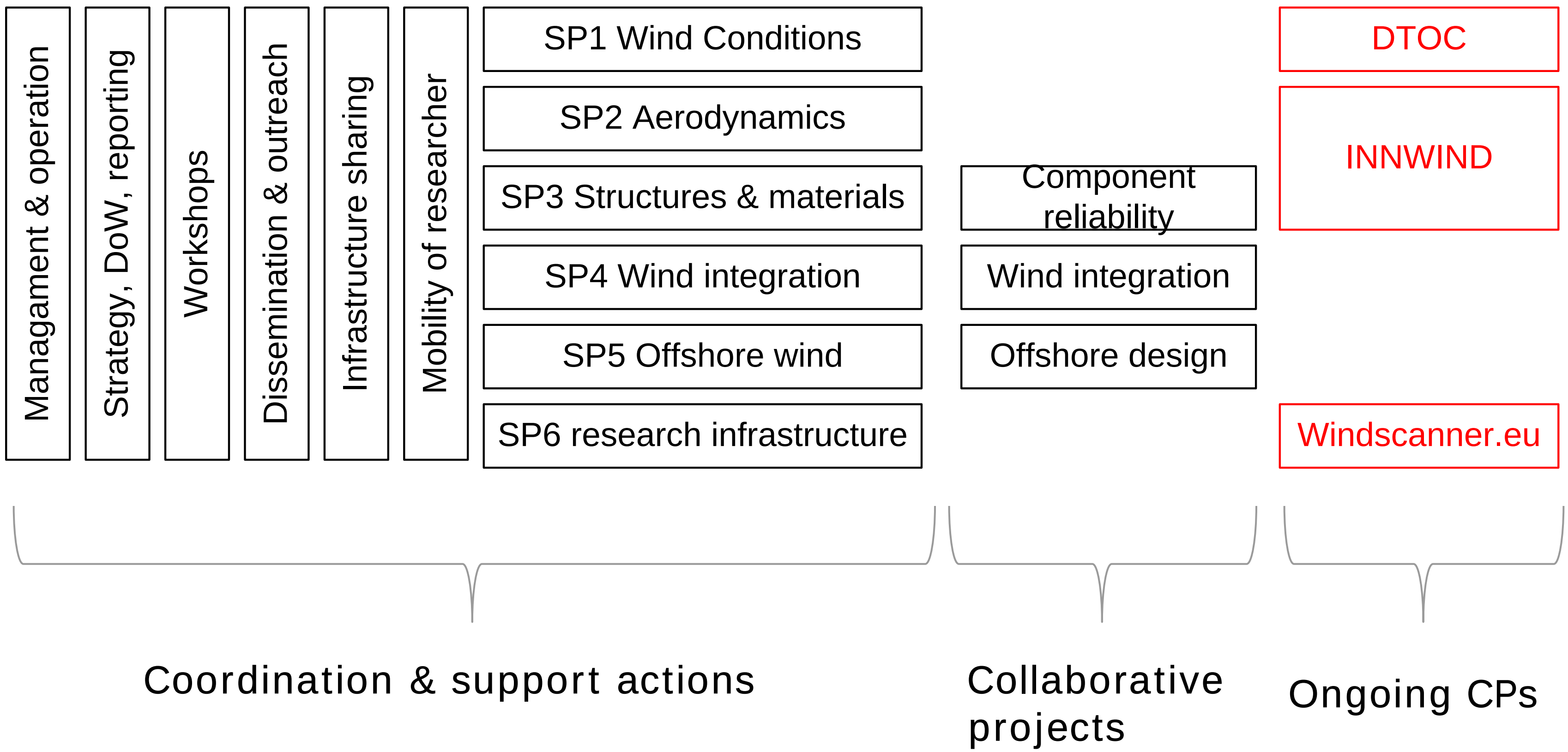
- **Wind Conditions**. Coordinated by Risø DTU in Denmark.
- **Aerodynamics**. Coordinated by ECN in the Netherlands.
- **Offshore Wind Energy.** Coordinated by SINTEF in Norway.
- **Grid Integration.** Coordinated by FhG IWES in Germany.
- **Research Facilities**. Coordinated by CENER in Spain.
- **Structures and Materials.** Coordinated by CRES, Greece



27 Research intitutes/universities from 13 European nations

Integrated Research Programme on Wind Energy – Proposal to EU FP7

Up to €10M per technology area
Duration of 4 years



Thank you for your attention